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SIMULATION OF SEA BASED LOGISTICS SUPPORT OF OPERATIONAL MANEUVER FROM THE SEA

by

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Operational Maneuver From the Sea (OMFTS) and its implementing concept, Sea Based Logistics (SBL), stress the need for logistically supporting forces ashore directly from a sea base. This study analyzes the capability of a current LHD-class amphibious ship to sustain a force deployed ashore through direct ship-to-objective movement of sustainment requirements. This study presents a baseline simulation model to estimate the ability of a LHD to deliver the required logistic support. Experiments were conducted with various scenarios and distances between the deployed forces and the nominal Sea Base (LHD). Sensitivity analysis was conducted to determine the effects of various parameters on the ability of the Sea Base to successfully accomplish the given scenarios with the specified conditions. Results indicate a substantial increase in the number of aircraft, operational availability of those aircraft, and/or a substantial reduction in sustainment requirements are needed in order to successfully accomplish the stated scenarios of this study. The results of this study could support the design of future LHD-class ships.

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SIMULATING SEA BASED LOGISTIC SUPPORT OF OPERATIONAL MANEUVER FROM THE SEA

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Submitted in partial fulfillment of the requirements for the degree of

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ABSTRACT

Operational Maneuver From the Sea (OMFTS) and its implementing concept, Sea Base Logistics (SBL), stress the need for logistically supporting forces ashore directly from a sea base. This study analyzes the capability of a current LHD-class amphibious ship to sustain a force deployed ashore through direct ship-to-objective movement of sustainment requirements. This study presents a baseline simulation model to estimate the ability of a LHD to deliver the required logistic support. Experiments were conducted with various scenarios and distances between the deployed forces and the nominal Sea Base (LHD). Sensitivity analysis was conducted to determine the effects of various parameters on the ability of the Sea Base to successfully accomplish the given scenarios with the specified conditions. Results indicate a substantial increase in the number of aircraft, operational availability of those aircraft, and/or a substantial reduction in sustainment requirements are needed in order to successfully accomplish the stated scenarios of this study. The results of this study could support the design of future LHD-class ships.

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I. INTRODUCTION

A. BACKGROUND

The end of the Cold War necessitated changes to the United States' National Security Strategy (NSS). The relative simplicity that a single, identifiable enemy with worldwide military capabilities and foreign policy objectives brought to the NMS was gone. The order of the Cold War was replaced by a new order characterized by uncertainty. This uncertainty resulted from instability caused by nations striving for regional hegemony, the dissolution of numerous other states resulting in humanitarian disasters, and the rise of internal, national conflicts based on religious and ethnic differences.

This new order of uncertainty and strife required the United States to drastically alter its NSS. The United States would no longer be able to concentrate solely on defeating the USSR. Instead, the United States would have to be able to counter instability, regional conflicts and humanitarian disasters anywhere around the world at any time in order to sustain the strategic advantage it gained at the end of the Cold War. Rather than World War III, the United States now expected to be involved in expeditionary operations covering the entire range of conflict intensity. And, since 75 percent of the world's population and 80 percent of national capitals are located in littoral regions, the littoral region can reasonably be expected to be the battleground of the near future where the United States' expeditionary operations will take place.

The transition of strategic focus from blue-water to littoral operations for the United States Navy and Marine Corps began in 1992 with its publication of “*from the Sea*”. This was followed by publication of a second publication in 1994 entitled “*Forward…from the Sea*” which further expanded the concepts of littoral operations. The Marine Corps continued to develop the littoral operations concept by creating a new vision for its most significant mission: amphibious assault. The vision was entitled Operational Maneuver From the Sea (OMFTS). [Ref. 14]

The OMFTS concept seeks to create and maintain a high operational tempo that overwhelms the enemy by striking directly from the sea at a center of gravity of the enemy. Striking the enemy directly from the sea accomplishes several objectives for the striking force. It avoids the traditional beach assault and logistics buildup required before the assault force can move against operational objectives. It maintains the element of surprise for the assault forces. It allows the assault force to exploit the maneuver space offered by the sea rather than having to create this space ashore by force. And it forces the enemy to defend all of his centers of gravity rather than only the beaches suitable for an assault stretching his forces thinner. [Ref 14]

However, despite the elimination of the logistics buildup requirement on the beachhead, the assault forces must still be logistically supported. And they must be supported over a potentially wider area since the assault force may be attacking widely separated operational

objectives. To this end the Sea Based Logistics (SBL) concept has been developed to support OMFTS.

Under SBL, the Marine forces inserted ashore will be supported from the ships at sea rather than the traditional shore based Combat Service Support Areas (CSSA). Logistics material will be delivered directly from the Sea Base to the operating units via aerial or surface transport assets. [Ref 16]

B. OBJECTIVES

The objective of this study is to analyze the capability of a current LHD-class ship to provide sustained logistic support to Marine units deployed ashore under the OMFTS concept.

C. RESEARCH QUESTION

The central research question of this study is: what scenario conditions, or parameters, most critically impact the ability of a LHD-class ship to provide the basic sustainment requirements (food, water, fuel, ammunition) for a typical Marine Expeditionary Unit, Special Operations Capable (MEU(SOC)) executing operational missions?

Sustainment requirements that must be determined include:

- What is the daily logistics requirement (food, water, fuel, ammunition) for a MEU(SOC)?

- Given the embarked lift capacity of a LHD (CH-53 and/or MV-22) what is the required cycle time to deliver the required logistics requirements?

- Given these sustainment requirements, this study will examine the impact of altering the value of various assumption parameters such as:
    1. the force package deployed in support of different operations,
    2. an increase in the number of aviation assets,
    3. the distance between the ships of the Sea Base and the deployed Marine units.

D. SCOPE

The focus of this research is to determine conditions that most impact the ability of our current and imminent inventory of Sea Base aviation and ship assets to sustain likely force packages deployed ashore. Determining this should then help point the way towards changes either in tactics and/or equipments necessary to ensure the feasibility and success of the OMFTS concept of operations. A secondary purpose of this research was to create a simulation of logistics sustainment operations under the OMFTS concept that could be used to model most future operations in advance as a planning aid.

Because the research focuses on the sustainment of forces, the actual deployment of those forces was ignored. It was assumed that the Marines were able to successfully

insert their forces in accordance with OMFTS. Additionally, any air cover missions that might be required for the logistics flights were ignored because of the additional complexity that would have been brought to the simulation. However, attrition for the logistics delivery airframes resulting from maintenance as well as enemy action is built into the simulation to closer approximate reality.

Surface delivery of logistic materiel was also ignored in this study. This was done to restrict the simulation to the strictest interpretation of OMFTS where absolutely no beachhead exists. If materiel were to be delivered anyway when no beachhead exists, there would then exist requirements for additional vehicles and personnel to be ashore to further transport the materiel on to the forces farther inland. This also assumes that those forces are reachable by passable roads. These transport forces would also create the requirement for secure interior lines of communication and delivery or at a minimum some sort of force protection and a secure laager as well. These requirements, in turn, would require more forces and lead us back towards the current amphibious assault doctrine and its CSSA approach.

Finally, a review of another pertinent thesis indicated that surface transport was only required at longer distances (> 100nm) from the shore to sustain the assumed deployed force package. However, the longer standoff distance required that significant logistics assets be placed ashore in order to increase the amount of on-hand days of supply for the forces ashore to counter the

increased shuttle time of the surface transports. [Ref 6] And, again this begins to lead us back to current assault doctrine and away from OMFTS principles.

E. LITERATURE REVIEW AND METHODOLOGY

Research included a review of the OMFTS, Ship-to-Objective Maneuver (STOM), and SBL concepts, and a review of previous Master's Theses addressing OMFTS sustainment operations. This was accomplished through a literature search of books, research documents, doctrinal publications and other library information resources. Completing this research also required developing plausible operational scenarios, creating a simulation model with Arena simulation software for the scenarios, analyzing the results of the simulation and making recommendations for future research and development.

F. ORGANIZATION

This chapter provided a general description of the project, the objectives of the research, the research question, the scope and limitations of the research project, and a brief description of the research methodology. Subsequent chapters are organized as follows:

II. OVERVIEW OF OMFTS AND SBL

III. SCENARIO

IV. SIMULATION MODEL

V. SIMULATION RESULTS AND ANALYSIS

VI. CONCLUSIONS AND RECOMMENDATIONS

II. OVERVIEW OF OMFTS AND SBL

A. INTRODUCTION

The methods and concepts of armed conflict are in a constant state of change. This results from a continuous flux in both the strategic and technologic environments that frame potential conflicts for which a nation must prepare. This state of flux requires a nation to continually refine and update the strategic, operational and tactical doctrines and operational concepts it expects to use in time of war against its expected and unexpected enemies. The United States now finds itself in a time of great change to both its strategic and technologic environment.

The end of the Cold War brought a huge amount of strategic uncertainty to the United States and the rest of the world. During the Cold War individual nations had been prevented or dissuaded by the two superpowers by any means necessary from beginning a conflict that could bring the two powers into conflict and possible nuclear exchange. Now, those nations could choose to pursue their national security or other objectives through force. The result has been a seemingly constant stream of conflicts and humanitarian disasters involving the United States' as it pursues its own national interests. The strategic forecast for the foreseeable future is more of the same.

In addition to the flux of the strategic environment since the end of the Cold War, there have also been great technological changes in the last decade. Information

gathering, management and dissemination methods and equipments have been revolutionized. In addition, conventional weapons have become more lethal and the mobility of forces on the battlefield has significantly increased [Ref 13]. The armed services of the United States have sought to leverage these advances to improve its ability to execute its assigned missions.

Facing these fundamental changes in both the strategic and technologic environments, the United States Navy and Marine Corps were forced to develop a new service strategy that would provide the best support to the nation’s National Security Strategy. This new naval strategy was first outlined in 1992 with the publication of *“…From the Sea”*. In this document the Navy recognized the changes to the strategic environment and looked to move its emphasis away from traditional open-ocean warfighting. Instead, the focus for the service shifted to joint operations conducted from the littoral regions of the world and the projection of power from the sea to the shore. [Ref 12]

In 1994, the Navy published *“Forward…From the Sea”*. This document updated and expanded the strategic concepts from the earlier white paper. It also stressed the importance of the Navy in preventing conflicts through forward deployments as well as the role of the Navy in humanitarian operations. [Ref 13]

The Marine Corps outlined its vision for operations in the littoral region in 1996. It built upon the foundation laid down by the Navy’s two concept papers and was entitled “Operational Maneuver From the Sea”.

B. OPERATIONAL MANEUVER FROM THE SEA (OMFTS)

In order to adapt to the changes in the strategic and technologic environment following the end of the Cold War, the Marine Corps developed OMFTS. OMFTS targets the littoral regions of the world as the arenas where the most important conflicts of the future will occur. Littoral regions are

> those areas characterized by great cities, well-populated coasts, and the intersection of trade routes where land and sea meet…littorals provide homes to over 80 percent of the world's capital cities and nearly all of the marketplaces for international trade [Ref 14].

OMFTS stresses that in order to influence world events, the United States requires a "credible, forwardly deployable, power projection capability" [Ref 12]. OMFTS further presses the need for this capability to be free of land bases and the restraints and constraints that come with use of those bases.

> …a sustainable forcible entry capability that is independent of forward staging bases, friendly borders, overflight rights, and other politically dependent support can come only from the sea [Ref 14].

In support of this goal, OMFTS envisioned rapid maneuver by assault forces from their ships directly to operational objectives ashore. Attacking objectives directly from the sea allows the Naval Commander to use the sea as maneuver space and turns the enemy's coastline into

a vulnerable flank rather than a barrier to entry. Under OMFTS the landing force is expected to create and maintain operational surprise, generate overwhelming tempo, and overmatch enemy weaknesses with its power and rapid execution in order to keep the enemy off-balance resulting in a quick, successful assault. This replaces the current amphibious methods of beach assault that require operational phases, pauses, and reorganizations that impose delays and inefficiencies on the operation. [Ref 15]

As the Marine Corps continued to develop OMFTS, it began to focus on the implementation of the concept. To that end two additional documents were issued. “Ship-To-Objective Maneuver”, published in 1997, addressed the tactical level of the OMFTS concept and “Seabased Logistics”, published in 1998, addressed the logistic sustainment of the forces sent ashore.

C. SHIP-TO-OBJECTIVE MANEUVER (STOM)

STOM is one of the key implementing concepts to achieve the operational goals established by OMFTS. STOM defines the principles and tactics of forcible entry from the sea. Two key components of STOM are the tactical maneuver of forces and seabasing.

Historically, amphibious warfare sought to move forces ashore methodically from the ships onto a beachhead via a slow-moving shuttle system. Forces would then expand out from the beachhead to seize intermediate and final operational objectives. However, this method was slow and restricted in its maneuver space and extremely vulnerable to enemy counterattacks. Until sufficient forces could be

lodged ashore and begin to develop operational momentum, the assault force was in a precarious position.

STOM seeks to change this ship-to-shore movement to amphibious maneuver.

Specifically, it will allow for conducting combined arms penetration and exploitation operations from over the horizon directly to objectives ashore without stopping to seize, defend, and build up beachheads or landing zones [Ref 14].

The objective of STOM is to put combat units ashore either by air, surface or both means in fighting formation in sufficient force and in the decisive place in order to accomplish the mission. The capability to operate from over the horizon (OTH) coupled with the ability to strike deep inland directly at centers of gravity will force the enemy to defend a vastly larger area and provide the attacking forces with tactical surprise. [Ref 15]

STOM also emphasizes using the sea as a maneuver space. Using the sea in this manner allows the landing force to take advantage of the enemy’s gaps by taking the axis of advance of their own choosing rather than one dictated by the topography of the coastal area. [Ref 14]

Another key aspect of STOM is seabasing. Under the STOM concept command and control, logistics and fire support remain at sea. Seabasing these functions produces several advantages for the OMFTS force. [Ref 15]

First, by keeping these functions at sea, they are invulnerable to attack from enemy ground forces. Second,

forces that would normally be tied up defending the facilities and Marines executing these functions can now be included in the direct assault force. Besides increasing the size and effectiveness of the assault force, this also serves to increase their mobility since they will not be tied to specific geographic areas, such as a beachhead or Combat Service Support Area (CSSA). Lastly, fewer ground troops sent ashore also means a reduced logistic sustainment requirement ashore for the assault force. This means fewer air or water craft have to be sent in to the shore exposing them and their personnel to loss or damage from enemy action or accident. Fewer sustainment sorties also free up aircraft for other combat duties, again increasing the combat power and effectiveness of the assault force. [Ref 15]

D. SEABASED LOGISTICS (SBL)

The success of STOM and OMFTS hinges on the ability to effectively seabase the logistic functions of the assault force.

By providing sustainment to operating forces ashore directly from an over the horizon base at sea, Seabased Logistics will allow the vision of Operational Maneuver From the Sea (OMFTS) and Ship to Objective Maneuver (STOM) to become reality [Ref 16].

Employing logistics directly from the ship to the objective will eliminate the requirements for beachheads. This will eliminate the resulting operational pause while sufficient supplies build up on the beachhead and also the

need for dedicated shore-based force protection for the logistics area.

Additionally, expectations are that future battlefields

will be characterized by coordinated speed of maneuver, increased operating ranges, and precision delivery of massed effects. Seabased Logistics offers the unique capability to both sustain the future high optempo battlefield and exploit the advantages inherent in mobility and over the horizon standoff [Ref 16].

There are five critical canons of SBL that must be implemented in order to properly sustain an amphibious assault force operating under OMFTS and STOM concepts. These elements are primacy of the sea base, reduced demand, in-stride sustainment, adaptive response and joint operations, and force closure and reconstitution at sea. [Ref 16]

1. Primacy of the Sea Base

The primacy of seabasing will be its ability to build, project, and sustain combat power. Forces will be assembled and sent ashore directly from the sea base, but most important, those same forces will be sustained from the sea base.

The sea base will be “an integrated over the horizon floating distribution center and workshop providing indefinite sustainment” [Ref 16]. The sea base is envisioned to possess the ability to provide all combat

service support functions afloat instead of ashore. [Ref 16]

Maneuver units will carry their initial support requirements with them in limited, mobile combat service support units and the sea base will then sustain them indefinitely by surface or by air as necessary. The sea base will then be replenished directly from sources in the continental United States (CONUS) or from around the world. [Ref 16]

With the reduced logistics footprint ashore, much of the double or triple handling of equipment and supplies in a CSSA arrangement will be eliminated. Additionally, a lack of immobile, shore-based logistics areas will also allow the logistics base to maneuver at sea with the operating forces. It will also free the forces ashore from protecting those logistics areas and subsequent interior lines of communications, allowing for greater operational initiative and maneuver freedom for the Naval Commander and the assault forces. [Ref 16]

Maintenance for both aviation and ground combat equipment will be critical to maintaining a high operational tempo for extended periods as well as the ability to reconstitute equipment after an operation has been completed. The sea base will provide at least the intermediate maintenance capability and will have access to spare parts through its sustainment network or by on-site fabrication. [Ref 16]

Seabasing the logistics also frees the amphibious force from the constraints and restraints associated with overseas basing rights and host nation support.

2. Reducing Logistics Demand

SBL will increase logistics efficiency and support through reduced demand on transportation and materiel resources. Improvements in operating efficiencies, reliability of equipment, precision ordnance and targeting, improved and alternate fuel efficiencies, should reduce demands for sustainment ashore. Improved information technology and rapid distribution will reduce the CSSA inventory stockpile ashore and allow sustainment materiel to be sent directly to the end user from the sea base. [Ref 16]

Demand will also be reduced because the command, fire support and combat service support functions will be located on the sea base. This reduces the footprint of forces ashore, thus reducing sustainment requirements, in particular fuel and ammunition requirements. Furthermore consolidating supplies aboard the sea base allows the amphibious force to carry fewer inventories. [Ref 16]

Demand reduction resulting from a more efficient employment of logistics resources will result in an increase in the numbers of fighting forces, combat power and agility that can be sustained ashore. [Ref 16]

3. In-Stride Sustainment

In-stride sustainment refers to the ability to provide sustainment materiel to fighting units without those units having to remain in place or withdraw to a rear area to assess and communicate its sustainment requirements.

Under this tenet of SBL highly automated requisition and distribution management systems will reduce costs and human interface and accelerate materiel movement. Total asset visibility will increase knowledge of materiel in-transit to the maneuver units as well as the on-hand inventories of those units. As a result, the fighting units will pull only the required sustainment materiel forward rather than large quantities of all materiels being pushed to the field in case it is needed. This "demand-based" system will lower inventory levels, allow for a management by exception approach to sustainment, and increase the efficiency of the logistics distribution system. [Ref 16]

4. Adaptive Response and Joint Operations

"Seabased Logistics will be fully capable of integrating with Theater Logistics" [Ref 16]. Major joint operations ashore may require the establishment of selected shore-based logistics systems. The sea base offers a means to initiate Joint Theater Logistics operations ashore. As initial operations expand and sustainment requirements exceed the capacity of seabased support, SBL will provide the ability to establish and maintain land bases for expanded operations and rapid closure of follow-on forces. [Ref 16]

5. Force Closure and Reconstitution at Sea

"Seabased force closure is the at sea arrival, assembly, and integration of operational forces to realize their combat power and coordinate associated logistics

sustainment” [Ref 16]. Combat forces and their associated equipment will be merged at sea prior to deployment ashore. Initial operational capability will be achieved prior to contact with the enemy and combat power will increase with the incorporation of any follow-on forces as they arrive. This eliminates the need for access to secure overseas ports and/or airfields to accomplish this necessary step and helps preserve tactical surprise for the assault forces. [Ref 16]

SBL will also reduce the time required for force reconstitution by retaining the command control, fire support and logistics forces afloat throughout an operation. The advancements in storage, distribution, and information technology will speed the return of forces to the sea base. This will provide the Naval Commander with greater flexibility to deal with any emergent situations. The interface with CONUS-based pipelines will allow the force to replenish personnel, equipment, ordnance and sustainment materiel and allow for those items needing significant maintenance to return to CONUS. [Ref 16]

Integral to the reconstitution of forces is the maintenance capability of the sea base. As mentioned previously, the sea base will have at least an intermediate level of maintenance capability for organic equipment. [Ref 16]

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III. SCENARIO

A. INTRODUCTION

In order to test the parameters that critically impact the ability of a LHD-class ship to provide basic sustainment requirements (food, water, fuel, ammunition) to a typical MEU(SOC) under the OMFTS concept, the scenarios under which the MEU(SOC) of the model are operating must first be outlined.

B. SCENARIO DEVELOPMENT

For this analysis to provide any meaningful results, there are a few requirements that the scenarios used in the simulation model must meet. First, the scenarios must be plausible. The range of missions the study’s MEU(SOC) are tasked with must be realistic and connected to the current strategic environment. Secondly, the forces actually sent ashore to accomplish the assigned mission must be realistic and commensurate with executing the mission. Thirdly, the underlying assumptions that govern the activity of the MEU(SOC) must be in accordance with the OMFTS concepts of operation.

With these requirements met, the objective of the chosen scenarios then is to provide different volumes of sustainment requirements. So, from the mission that the MEU(SOC) is assumed to be engaged in, we develop the likely force structure required to execute the mission. The size and inventory of the force structure then determines the

quantities of supplies that must be delivered ashore to sustain the forces executing the mission.

Once the volume of sustainment requirements for each mission is determined, the simulation model will be used to determine what scenario conditions, or parameters, most critically impact the ability of a LHD-class ship to provide the basic sustainment requirements to the forces ashore.

To test these parameters, each of the three volumes of sustainment requirements (derived from the different missions) will be run through the simulation model with a variety of distances between the Sea Base and the forces ashore to determine what percentage of the sustainment requirements can be delivered on a daily basis. Following this, sensitivity analysis will be done on the missions and distances where the 100 percent of the sustainment requirements could not be delivered. This will be done to determine if increasing the number of aviation assets or utilizing more take-off/landing spots at the Sea Base would improve the daily delivery percentage.

As an example, one of the missions is a humanitarian mission. For the study, the sustainment requirements for the forces required for the mission are input into the simulation. Then a distance of 50 miles between the Sea Base and the forces is also input into the simulation model. The simulation is then run numerous times to determine the percentage of the requirements that can be delivered each day. An average percentage for each day is then calculated. For those days where, on average, 100 percent of the sustainment requirements cannot be

delivered, the simulation is rerun using increasing numbers of aviation assets. This is then repeated with the number of take-off/landing spots at the Sea Base.

As a result, the key parameters of the scenario include the forces deployed ashore, the type of mission executed, the distance between the Sea Base and the deployed forces, the aviation resources of the Sea Base, the sustainment requirements of the deployed forces and other major assumptions that affect the scenario.

1. Forces

The Marine Air-Ground Task Force (MAGTF) is the principal organization used by the Marine Corps for missions that span the range of military operations. The MAGTF is composed of four elements: a command element (CE), a ground combat element (GCE), an aviation combat element (ACE) and a combat service support element (CSSE). The MAGTF can vary in size from the Marine Expeditionary Force (MEF) that is comprised of a full Division and Air Wing down to the Marine Expeditionary Unit (MEU) that contains a single Battalion and an Aviation Squadron.

The standard forward deployed Marine expeditionary organization, however, is the MEU(SOC). The (SOC) appellation is applied to the MEU following completion of a rigorous pre-deployment training program and demonstration of proficiency in executing various missions that span the range of operations the MEU may encounter.

The MEU CE is the standing headquarters and staff of the deployed forces. It is augmented for deployment by

elements of Force Reconnaissance, an Intelligence Company, and a Communications Battalion. [Ref 7]

The MEU GCE is a Battalion Landing Team (BLT). A BLT is built around an infantry battalion with its staff, three Rifle Companies, a Weapons Company, and an organic communications section. It is augmented with an artillery battery, a combat engineer platoon, a Light Armored Reconnaissance Company, an Assault Amphibian platoon, and in some instances a section of Tanks. In this simulation the Advanced Assault Amphibious Vehicle (AAAV) is used instead of the current AAVs in service because the AAAV is identified as a key component of OMFTS. [Ref 7]

The MEU ACE is designated as a Composite Squadron. It is normally built around a Marine Medium Helicopter Squadron (HMM) of 12 CH-46 Sea Knights. However, the CH-46 is scheduled to be replaced by the MV-22 Osprey and therefore the MV-22 is used in the simulation model of this study. The HMM is augmented by four CH-53E Sea Stallions from a Marine Heavy Helicopter Squadron as well as three UH-1N utility helicopters and four AH-1W Sea Cobra attack helicopters, both of which come from a Marine Light Attack Helicopter Squadron. A fixed-wing capability is provided by six AV-8B Harriers from a Marine Attack Squadron. [Ref 7]

The MEU CSSE is designated as a MEU Service Support Group (MSSG). The MSSG consists of a staff, a supply detachment, a maintenance detachment, a motor transport detachment, a landing support detachment, a communications section, a health services detachment, an engineer support

detachment, a military police section, as well as disbursing and postal representatives. [Ref 7]

These then are the forces that the force commander can draw from in order to accomplish the various missions he may encounter while on deployment. Depending on the mission, the commander will draw up a different force package of people and equipment.

2. Mission Types

The mission types used in the simulation model were drawn from Captain Robert Hagan’s Master’s Thesis, Modeling Sea-Based Sustainment of Marine Expeditionary Unit (Special Operations Capable)(MEU(SOC)) Operations Ashore [Ref 7]. Captain Hagan detailed five missions that a MEU(SOC) was likely to face and was capable of accomplishing. For those missions he provides realistic situations along with likely force compositions and a brief concept of operations for each mission.

From these five missions, three were chosen for this study. These missions were chosen to provide a range of force requirements of low, medium and high that, in turn, produce low, medium and high sustainment requirements. The three missions chosen and used in the simulation model of this study are Humanitarian Assistance/Disaster Relief, Non-Permissive Non-Combatant Evacuation Operation, and Enabling Force Operation.

a. Humanitarian Assistance/Disaster Relief (HA/DR)

Situation: A natural disaster has occurred in a developing nation resulting in a situation similar to Bangladesh following a 1991 typhoon. The deployment of a Joint Task Force (JTF) is hampered by extensive damage to the nation's infrastructure such as strategic lift capable airfields and ports. A deployed MEU(SOC) is deployed to provide an initial stabilizing response and to prepare for the delivery of humanitarian relief supplies. [Ref 7]

Force Composition: The force for this mission is built around the MEU(SOC)'s ability to generate and distribute logistical support. There is little need for command and control from the CE and security forces from the GCE. In addition to personnel, the GCE also contributes Light Armored Vehicles (LAVs) and AAAVs for all terrain distribution capability and combat engineers for their construction skills. The ACE provides its bulk fuel capability and some communications assets. The CSSE provides the majority of the people and equipment ashore including motor transportation and health service capabilities. [Ref 7]

Concept of Operations: Establish the force ashore in order to distribute relief supplies, provide potable water, assist in the clearing of debris, provide power generation in priority areas, and provide medical assistance. The focus of effort is delivery of relief supplies in the near future. Shore based storage for

potable water, fuel, and dry supplies for MEU(SOC) forces is limited. Sustainment requirements were determined only for the force ashore as they prepare for the arrival of the relief supplies to be distributed. [Ref 7]

b. Non-Permissive Non-Combatant Evacuation Operation (NEO(N-P))

Situation: Civil disorder in a developing nation is rapidly deteriorating into chaos. The host nation has lost its ability to control the situation. A number of United States' citizens require evacuation. As a result, a larger, more capable force is required. A deployed MEU(SOC) is ordered to conduct the mission. [Ref 7]

Force Composition: The larger force results mainly from an increase of the GCE, which now includes some command sections ashore. Additionally, the ACE provides a forward refueling capability for what could evolve into a mission of longer duration. The CSSE's contribution also grows to deliver a robust Evacuation Control Center (ECC). [Ref 7]

Concept of Operations: Deploy the security force, the ECC, and the liaison and coordination elements of the CE. Conduct the evacuation. [Ref 7]

c. Enabling Force Operation

Situation: An ongoing border dispute between two developing nations has intensified with the invasion of one

nation by the other. The invaded nation has requested intervention by the United States. A deployed MEU(SOC) is directed to seize and secure both a port and an airfield to enable the deployment of follow-on forces. [Ref 7]

Force Composition: This mission requires the entire GCE ashore with the exception of the CE. Under OMFTS concepts command and control will be exercised from the Sea Base. The ACE provides air control communications, refueling and anti-air assets. The CSSE provides motor transportation, general engineering, landing support, and maintenance assets. [Ref 7]

Concept of Operations: Establish a force ashore to include artillery in order to seize and secure the port and airfield. [Ref 7]

Table 1 summarizes the key information for each mission. [Ref 7]

Mission	People	HMMWVs and Trailers	5-Ton Trucks	Logistics Vehicle Systems	Light Armored Vehicles	Advanced Assault Amphib Vehicles	M198 Howitzers
HA/DR	CE: 25 GCE: 158 ACE: 24 CSSE: 210 417	67	21	5	14	13	0
NEO(N-P)	CE: 20 GCE: 516 ACE: 35 CSSE: 80 651	51	15	1	15	0	0
Enabling Force	CE: 0 GCE: 1260 ACE: 35 CSSE: 210 1505	118	30	5	18	13	6

Table 1. Mission Development Summary. After Ref [7].

3. Distances

Three distances (radius) from the sea base to the forces deployed ashore were chosen for the simulation model: 50, 100, and 150 miles. 50 miles was chosen as the minimum distance directly from Ship-to-Objective Maneuver where it is envisioned as the minimum standoff distance of the Sea Base from a hostile shore when delivering assets via the air. 100 and 150 miles were chosen as round multiples of the minimum distance that would stretch the limits of the OMFTS concept.

Increasing the distance decreases the payload of the MV-22 because of fuel constraints. This reduced payload results in more sorties required within the given flight

hours available in a day creating a potential point of failure for the OMFTS concept.

4. Aviation Assets

The HMM component of the MEU(SOC)’s ACE for this simulation consists of 12 MV-22 Ospreys and four CH-53E Super Stallions.

a. MV-22 Osprey

The MV-22 Osprey is the Marine Corps replacement for the CH-46E medium lift assault helicopters. The MV-22 is a tilt-rotor aircraft, which can take off and land vertically like a helicopter, then fly like an airplane. Using this technology, the MV-22 will be able to travel further, at much higher speeds and with a much larger payload than the fleet of aircraft that it is replacing. The MV-22 has not been introduced to the fleet yet and has recently encountered programmatic difficulties, but it is envisioned to be fully operational by 2010. [Ref 7]

The MV-22 will not provide a great speed advantage with regards to the movement of external loads since its speed, in this case, will be constrained by the load’s profile. The speed of a MV-22 carrying an external load is 167 knots [Ref 10]. Unladen, the MV-22 flies at 230 knots [Ref 10]. MV-22 deliveries of cargo will be accomplished via external means because of constraints imposed by cabin dimensions and cargo floor weight limitations. [Ref 7]

Because the model takes into consideration the tradeoff between range and payload below, the total available flight time of a single aircraft is constant. This results because the reduction in payload is replaced with additional fuel to ensure the aircraft can reach the extended distance. For the MV-22s in this analysis, total flight time between refuelings is assumed to be 4 hours.

b. CH-53E Super Stallion

The CH-53E Super Stallion is the Marine Corps heavy transport helicopter. While this helicopter can accomplish the same missions as the MV-22, the CH-53E is mostly utilized for its ability to externally lift heavy oversized equipment. The CH-53E is also used tactically for its capability to position/reposition artillery units in support of reducing the effects of enemy counter-battery fire. [Ref 7]

In this simulation model, the four CH-53E of the ACE are not used for sustainment requirement sorties. They are reserved for heavy lift missions the MV-22s are not capable of accomplishing such as artillery or heavy equipment movement or for transporting heavy equipments to the Sea Base for maintenance.

c. Range vs. Payload

For helicopters and tilt-rotor aircraft, there is a direct trade-off between useful load and fuel. The cargo’s weight as well as the packaging of the cargo also limits the movement of cargo. Water and fuel are

transported in 500-gallon bladders while MREs and ammunition are transported with nets loaded with pallets.

Table 2 provides the maximum payload for each mission radius [Ref 7].

Mission Radius (miles)	MV-22 External Lift (lbs)
50	11,482
100	9,362
150	7,184

Table 2. Mission Radius vs. Cargo Payload. After Ref [6]

Each bladder of water weighs 4,650 pounds including the weight of the bladder [Ref 11]. Each bladder of fuel weighs 3,685 pounds including the weight of the bladder [Ref 11]. A pallet of MREs weighs 1,100 pounds based on a weight of 1.46 lb/MRE and the weight of the packaging and pallet [Ref 7]. An ammunition pallet weighs 2,200 pounds including the weight of the packaging and pallet.

Table 3 provides the maximum number of pallets in the payload of a single MV-22 for each mission radius. The actual number of pallets of each type of requirement is based on the number and type of forces, vehicles, and equipment deployed ashore and is treated in the next section.

Mission Radius (miles)	Pallets of MREs	Pallets of Ammunition	Bladders of Water	Bladders of Fuel
50	10	5	2	3
100	8	4	2	2
150	6	3	1	1

Table 3. Mission Radius vs. Maximum Requirement Payload

d. Maintenance Requirements

Over time, aircraft experience breakdowns and require maintenance. This maintenance can be either routine, minor organizational-level maintenance or major AIMD-level maintenance requiring an intermediate level capability to repair the aircraft. Under the OMFTS concept, the Sea Base is assumed to have this capability.

In the simulation model used here, the MV-22 is assumed to have an operational availability of 85 percent [Ref 4]. Additionally, the 15 percent of aircraft that require maintenance are given an 80 percent chance of requiring minor maintenance that takes the aircraft out of use for an average period of three hours (180 minutes). Major maintenance occurs 20 percent of the time and removes the aircraft from service for an average period of 25 days (600 hours or 36,000 minutes).

Both of these maintenance periods were simulated using an exponential distribution. This type distribution was used because there is a large amount of variance in the data used to calculate the mean. Data from air-capable amphibious ships in the NALDA database was used to calculate the mean delay times. While the mean was equal

to 25 days, there were many extreme values. These extremes usually result from the reporting activity being on deployment. Extended supply lines increase the reported delay times because the difficulty of obtaining materiel and the required replacement spares. However, the status of which ship was on deployment when is unknown. For example, data from the USS Wasp showed a range from five to 257 days delay. So, because of the high variance in the data and the fact that the true distribution for major maintenance for the MV-22 is unknown at this time, an exponential distribution was used. As data becomes available as the MV-22 is introduced into the fleet, this distribution should be revisited in order to improve the results of the model. [Ref 8]

5. Sustainment Requirements

The daily quantity of each type of sustainment requirement is based on the number and type of the forces, vehicles and equipment deployed ashore by the force commander. This study uses existing Marine Corps Logistic Planning Factors (LPF) published in the MAGTF Data Library. Supplies other than the four used in this study were not considered significant for the types of missions analyzed. In all cases fractional numbers were always rounded up to the nearest whole number.

a. Meals Ready to Eat (MRE)

MREs are consumed at a constant rate of three MREs per person per day. The number of pallets of MREs that are required each day is calculated:

$$M = \frac{(N \times D)}{576}$$

Where M = total daily MRE requirements in pallets
N = number of personnel ashore
D = daily MRE requirement per person
576 represents a pallet of 48 cases containing 12 MREs per case. [Ref 7]

b. Water

The daily requirement for water among the deployed force is dependent on climate, exertion level, hygiene, and equipment types. Water usage can range from 4 to 10 gallons per day per person. For this study, the usage rate is 6 gallons per day per person [Ref 16]. The number of bladders of water required each day is calculated:

$$H = \frac{(N \times W)}{500}$$

Where H = daily water requirement in bladders
N = number of personnel ashore
W = daily water planning factor in gallons
500 represents the number of gallons per water bladder. [Ref 7]

c. Ammunition

Ammunition requirements are a function of ammunition type, weapon type, threat, and the phase of combat. The number of pallets of ammunition required each day is calculated:

$$A = \frac{\left(\sum_{i}\sum_{j} Q_{ij} \times Y_i \times V_j\right)}{2,200}$$

Where A = total daily ammunition requirements in pallets

Q_{ij} = rounds per day for ammunition type i used by weapon type j

Y_i = weight of ammunition type i round in pounds

V_j = number of weapon type j ashore

2,200 represents the number of pounds of ammunition that can be loaded on a single pallet. [Ref 7]

d. Fuel

Fuel requirements are a function of equipment type and numbers of equipments deployed ashore. For each item of equipment, a daily requirement is computed based on planning factors for gallons per hour and operating hours per day. The number of bladders of fuel can be calculated:

$$F = \frac{\left(\sum_{j} X_j \times Y_j \times E_j\right)}{500}$$

Where F = daily fuel requirements in bladders

X_j = fuel use in gallons per hour for equipment type j

Y_j = operational hours per day for equipment type j

E_j = number of equipment type j ashore

500 represents the number of gallons per fuel bladder. [Ref 7]

Table 4 summarizes the daily requirements in pallets for food and ammunition and bladders for fuel and water for each type of mission. [Ref 7]

Mission	MREs	Water	Fuel	Ammunition Assault Rate	Ammunition Sustained Rate
HA/DR	3	5	10	0	0
NEO(N-P)	4	8	10	7	2
Enabling Force	8	19	20	29	7

Table 4. Mission Daily Sustainment Requirements

6. Other Assumptions

In addition to the parameters discussed previously, there are several additional assumptions that affect the simulation model developed for this analysis.

First, it is assumed that the enemy air defenses and air assets were neutralized prior to the insertion of the Marines. Thus there is no attrition to the MV-22s flying resupply missions due to enemy action in this simulation model. Support for this assumption can be drawn from recent examples of United States intervention in Kosovo, Afghanistan and the Gulf War.

Secondly, this analysis assumes the entire force that will be deployed has been deployed prior to the start of the resupply missions. Therefore, there is little requirement for aircraft to ferry personnel from the Sea Base to the shore. This leaves all MV-22s initially available for resupply sorties. Any requirement for minor reinforcement or medical evacuation is assumed to be filled by the ACE complement of UH-1N utility helicopters.

Lastly, it is assumed that the MEU(SOC) forces that were deployed ashore did not secure any beachhead and are sufficiently far enough away from any usable beaches to preclude the use of any sort of surface transportation to deliver the sustainment requirements. This includes both the Sea Base’s complement of LCACs and any other lighterage.

IV. SIMULATION MODEL

A. INTRODUCTION

A simulation model provides the means to replicate a system or process over a period of time without expending the resources required for an experiment with the physical system. Relatively inexpensive computing power that is readily available has greatly expanded and encouraged the use of this capability.

The simulation model developed for use in this analysis is based on the OMFTS and SBL concepts. It incorporates the elements and boundaries of the scenario detailed in Chapter III. The purpose of the simulation is to create a virtual system and then exercise it in order to measure its performance under the varying conditions of the simulation model.

This chapter provides a description of the simulation model used in this analysis. It describes the logic behind the model and how the model functions in order to create and deliver the sustainment needs of a force deployed ashore.

B. SIMULATION

The simulation model created for this analysis was done using the Arena® simulation software. In order to work through the logic of the simulation model in an organized manner, the discussion of the simulation is broken down

into the following areas: Shore, MREs, Ammunition, Fuel and Water, MV-22, General Resources and Statistics.

The logic flow for each of these areas is discussed, but the reader must keep in mind that these areas do not operate independently. Each of the areas is interconnected with the others and operate as an integrated whole to produce the complete, continuous system model. Additionally, it is important to note that the simulation model operates in the same fashion no matter which of the sustainment requirements levels (HA/DR, NEO(N-P), or Enabling Force scenarios) is input into the model.

1. Shore

The objective of the area of the model depicting the forces ashore is to generate a constant, daily demand for sustainment requirements and to receive the requirements via MV-22 Osprey from the Sea Base LHD.

The simulation begins at time 0000 hours. The forces are assumed to have deployed the previous day. For the purposes of the analysis it is also assumed that they have two full days of supply onhand at the beginning of the simulation. Any supplies needed for the first day’s deployment and limited operations were taken with the forces in addition to the two days of supply (DOS) in their limited, mobile combat logistics trains.

At time 0000 hours an entity is created in the model and then immediately delayed for 20 hours. This delay approximates the first full day of the operations where the Marines consume one of their two DOS onhand. At 2000 hours the deployed forces relay their sustainment requirements

back to the Sea Base as envisioned in the OMFTS concept. The requirements are not reported until the Marines cease operating for the day and therefore, it is too late in the day for the MV-22s to fly resupply missions.

The entity is then delayed 24 more hours. At that point, it is 2000 hours of day two. Again, requirements are transmitted to the Sea Base. This loop continues indefinitely, creating a “pull system” for the daily demand of sustainment requirements as listed in Table 4.

On the second day beginning at 0700 MV-22s begin bringing the sustainment requirements requested the previous evening. The amount of time required for the aircraft to arrive is based on the speed of the aircraft when carrying an external load, 167 knots, and the distance between the Sea Base and the deployed forces (50, 100, or 150 miles). Once the aircraft drops its load it is routed back to the Sea Base at 230 knots.

Aircraft will continue to shuttle between the Sea Base and the deployed forces until all of the daily requirements have been delivered or until 1900 hours each day of the simulation. This provides for 12 hours of available flight time for each aircraft each day.

Once the aircraft have dropped off their loads, the loads are sorted according to the type of commodity (MRE, ammo, fuel, water). They are split from the MV-22 load batch size based on Table 3 into individual pallets. The number of pallets is then counted and compared to the number of pallets that were requested.

2. MRE

The objective of the MRE area of the simulation is to create the daily quantity of MRE pallets required by the forces ashore and then move them to the staging area on the flight deck where they are picked up by a MV-22 for transport to the shore.

When the scenario reaches 0000 hours (1440 minutes of scenario clock time) of the second day a number of entities representing pallets of MREs are created in Hold X of the LHD-class ship. No pallets are created on the first day of the simulation. This is because the Marines ashore are in the act of consuming a DOS and will not communicate their sustainment requirements until the end of day one. The number of MRE pallets created is equal to the daily requirement generated by and dependent on the size of the force deployed ashore as shown in Table 4. This is then repeated every 24 hours.

Following their creation in Hold X, the MRE pallets are placed on Elevator 5 in order to get from the hold to the Aircraft Hangar Deck. The pallets are grouped into batches of no more than four to conform to the capacity restrictions of Elevator 5.

The time required for the elevator to move between decks is simulated using a uniform distribution with a minimum of two minutes and a maximum of three minutes. The uniform distribution was chosen because it bounds the elevator speed on both sides of the distribution. The minimum time required is based on an empty elevator moving between decks while the maximum time required is based on the elevator moving between Hold X and the Hangar Deck with

a capacity load. Because the weight placed on the elevator varies with the batch size up to the maximum size and/or weight limits, all values between the minimum and maximum times are equally likely but will not exceed the minimum and maximum. Uniform distributions are utilized for the movement of all elevators in the simulation for these reasons.

Once Elevator 5 reaches the Hangar Deck, the pallets are removed from the elevator and moved one pallet at a time via forklift to the Aircraft Elevator located at the starboard aft corner of the ship. The movement times of the hangar deck forklifts, like the elevators is controlled using a uniform distribution. The reasoning is the same, with the minimum time based on an empty forklift and the maximum time based on a fully loaded forklift.

At the Aircraft Elevator the pallets are grouped into batches of no more than 20 to conform to the capacity restrictions of the Aircraft Elevator. The Aircraft Elevator then moves the pallets up to the flight deck. A uniform distribution is again used to simulate the required times of the elevator. For this elevator the minimum time is two minutes and the maximum time is four minutes.

Once the pallets reach the flight deck, they are again moved one at a time by forklift. Just like the hangar deck forklifts, these flight deck forklifts’ movement times are managed using a uniform distribution with a minimum of two minutes and a maximum of four minutes. The pallets are moved to a staging area to be batched for transport by the MV-22s. The maximum batch size for the movement ashore is

based on the distance between the forces ashore and the Sea Base as shown in Table 3.

3. Ammunition

The objective of the Ammunition area of the simulation is to create the daily quantity of ammunition pallets required by the forces ashore and then move them to the staging area on the flight deck where they are picked up by a MV-22 for transport to the shore.

When the scenario reaches 0000 hours of the second day a number of entities representing pallets of ammunition are created in Hold 1 of the LHD-class ship. No ammunition pallets are created on the first day of the simulation for the same reason discussed in the MRE subsection. The number of ammunition pallets created is equal to the daily requirement generated by and dependent on the size of the force deployed ashore as shown in Table 4. This is then repeated every 24 hours.

Following their creation in Hold 1, the ammunition pallets are placed on Elevator 1 in order to get from the hold to the Flight Deck. The pallets are grouped into batches of no more than four to conform to the capacity restrictions of Elevator 1. The movement time of this elevator is managed by a uniform distribution just like the elevators used to move the MRE pallets. The minimum time for Elevator 1 is four minutes and the maximum time is six minutes to move from Hold 1 up to the Flight Deck.

Once the pallets reach the Flight Deck, they are moved one at a time via the flight deck forklifts governed by the uniform distribution times listed in the MRE subsection.

They are moved to a staging area to be batched for transport by the MV-22s. The maximum batch size for the movement ashore is based on the distance between the forces ashore and the Sea Base as shown in Table 3.

4. Fuel and Water

The objective of the Fuel and Water areas of the simulation is to create the daily quantity of fuel and water bladders required by the forces ashore and then move them to the staging area on the Flight Deck where they are picked up by a MV-22 for transport to the shore.

As in the previous areas of the model, fuel and water bladders are created at 0000 hours of the second day. Following their creation the fuel and water bladder entities are delayed 30 minutes to approximate the time required to fill the bladders on the Flight Deck. Once the pallets are filled, they are moved one at a time via the flight deck forklifts, governed by the uniform distribution already described, to a staging area to be batched for transport by the MV-22s. The maximum batch size for the movement ashore is based on the distance between the forces ashore and the Sea Base as shown in Table 3.

5. MV-22

The objective of the MV-22 area of the simulation is to create the MEU(SOC)s complement of 12 MV-22s, match them with batches of commodities for transport ashore and return them to the Sea Base for matching with another batch of commodities. This process is a continuous loop and also

includes logic for refueling and maintenance of the aircraft.

After the creation of the MV-22 entities, they move to a waiting station. Now, for the simulations performed for this study, it was assumed there were 12 available flight hours, 0700 hours to 1900 hours, for the MV-22s to use. In order to simulate these hours and prevent the MV-22s from flying outside of these hours, a variable called “Flag” was incorporated into the model. And, depending on the value of the Flag variable, the MV-22s were either able to depart the Sea Base or prevented from departing.

So, following their creation, the MV-22s arrive at a waiting station. There they check the value of the Flag variable. If the Flag is equal to one, aircraft are allowed to proceed forward, pick up a batch of commodities for delivery, and depart the ship for the shore landing zone. If, however, the Flag is equal to two, no aircraft may proceed beyond the waiting station until the value of the Flag changes back to one.

The value of the Flag variable is controlled by a logic chain independent from the rest of the simulation model. At the beginning of the simulation (0000 hours of the first day) a single entity is created in this logic chain. It is then delayed seven hours, until 0700 hours. Once the entity continues on, it changes the value of the Flag variable to one. The entity is then delayed for 12 hours creating the 12 hours of available flight time. At time 1900 hours, the entity changes the Flag variable back to a value of two, halting all flight. The entity is then delayed another 12 hours (until 0700 hours the next day)

and returned to the module that changes the Flag variable back to one. This process continues in a continuous loop for the rest of the model creating a flight window from 0700 hours until 1900 hours every day of the simulation.

If the MV-22 entities are allowed to fly, they seize one of the available landing spots on the Sea Base ship and are then matched with a batch of commodities. The entity is then delayed five minutes to approximate the time required to hook up the nets used to transport batches of pallets and to clear the Sea Base area. The MV-22 then releases the landing spot, making it available to another MV-22 and then continues on to deliver the batch of commodities to the forces ashore.

The amount of time required for the aircraft to travel to the shore is based on the speed of the aircraft when carrying an external load, 167 knots, and the distance between the Sea Base and the deployed forces (50, 100, or 150 miles). Each of the route times for the three different distances is governed by a triangular distribution. This is because there is a minimum time for the flight because the distance and the maximum allowable speed with an external load are fixed values. The aircraft can cover the distance in no less time than the minimum, but can exceed this time. This longer route time could be a function of the pilot's experience, weather, profile of the load or several other factors not quantifiable in this study.

Because of the need to bound the distribution for the flight times on the left with a minimum and still maintain a realistic mean time for the route time, a triangular

distribution was used. The minimum parameter is the amount of time required to cover the distance from the Sea Base to the forces ashore at the maximum speed, 167 knots. The mode for the distribution was made to be slightly higher as the distance increased. For instance, the minimum and mean of the shortest distance is 18 and 19 minutes respectively while the mininum and mean for the longest distance is 54 and 57 minutes respectively. The maximums for the route times were also adjusted according to the distance to cover. This simulates the effect of the longer flight time allowing for more factors to affect the aircraft or pilot and slowing the delivery time.

Upon reaching the landing zone the MV-22 is delayed five minutes to approximate the time required to approach the landing zone and then disengage its external load. The MV-22 then returns to the Sea Base to pick up another batch of commodities for delivery. The route times back to the Sea Base are treated in the same manner as the route times from the Sea Base. There is a difference, however, in the maximum speed of the aircraft. Since it no longer carries an external load, this speed is 230 knots.

When the MV-22 arrives at the Sea Base the model checks to see if the aircraft requires fuel or maintenance. The first check is for maintenance. 85% of the returning aircraft are forwarded to the refueling check station while 15% are sent to have maintenance done. This approximates the targeted .85 operational availability of the MV-22 [Ref 4]. This approach method may result in a lower than targeted operational availability in the long run, however,

for this study it is assumed it is acceptable for the short-term scenarios that are simulated.

Of the aircraft that require maintenance, 20% will require intermediate maintenance by the AIMD of the Sea Base while the other 80% will only require minor, organizational maintenance. This 80/20 split is based on discussions with former and current AIMD Maintenance Officers with significant operational experience with both fixed-wing and rotary-wing aircraft.

Those aircraft requiring organizational maintenance are delayed a period of time defined by an exponential distribution with a mean of three hours as its parameter. These parameters were also derived from discussions with former and current AIMD Maintenance Officers with significant operational experience with both fixed-wing and rotary-wing aircraft.

These organizational-level repairs are those that require minimal or no post-maintenance testing and are concerned with replacing items on the airframe that are easily accessible. Examples include fuse replacement or replacing a windshield wiper assembly.

Those aircraft requiring AIMD maintenance are delayed a period of time defined by an exponential distribution with a mean of 25 days as its parameter. These parameters were derived from the NALDA database. It is based on reported a Repairable Item Turn-Around Time Summary for aviation-capable amphibious ships for the period July 2000 to July 2001.

These AIMD-level repairs are those requiring repairables as well as significant post-maintenance testing or phase maintenance testing requirements and/or require significant disassembly of various aircraft systems to access the failed part or module. Examples include repair or replacement of the radar or communication system modules or repair work on a significant system such as the hydraulics.

The refueling check is accomplished by means of an attribute called Refuel Time. This attribute is initially assigned a value equal to whatever the current time is, called TNOW in Arena. This is done after the wait station where the MV-22s wait for the Flag variable to change to one and just prior to seizing the landing spot for picking up a commodity batch for delivery on the first day. The positioning of this attribute assignment allows for the MV-22s to begin each day with a full load of fuel. During the 12 hours each day when flight operations are capable, this station is avoided by the entities because the Flag variable is equal to one and the MV-22s are not routed to the wait station. Therefore, during the flight operations window the value of the Refuel Time attribute must be assigned elsewhere.

When the aircraft returns to the Sea Base, the Refuel Time attribute is compared to its time of return. If the difference is greater than 240 minutes (four hours), the aircraft is routed for refueling. The MV-22 entity seizes a landing spot on the Sea Base ship and is then delayed to approximate refueling based on a triangular distribution.

A triangular distribution is used here because there is a “most likely” time with some variation around that time and a minimum and maximum time. The distribution is bounded on the lower end by the flow rates of the various valves involved in the fuel transfer bounded on the upper end by the level of experience of the personnel performing the transfer. This triangular distribution that controls the refueling time is defined by the minimum, mode, and maximum values of 15, 20, and 30 minutes [Ref 10].

Following this delay, the Refuel Time attribute is reset to the current time, TNOW, allowing for a further four hours of flight time. The entity then releases the landing spot, making it available once again and is returned to service with the rest of the MV-22s.

Additionally, it is assumed that those aircraft that are delayed for maintenance will also be refueled during its maintenance delay time. Following the maintenance delay the aircraft are returned to service with the rest of the available MV-22s.

6. General Resources

Resources in Arena simulations act as pools that the entities of the system draw upon to fill a need. In order to utilize the resource, an entity first seizes one of the available resources. This resource is then unavailable to any other entity in the simulation. Once the entity has used the resource for its intended purpose, it releases the resource. This returns the resource to the pool to be drawn upon by other entities. If there are no resources available, the entity must queue up and wait for one of the

resources to become available. Two elements of the simulation model were modeled as resources: flight deck forklifts and landing spots for the aircraft.

The flight deck forklifts were modeled as resources because of the difficulty of simulating the forklifts selecting which of the four commodities to retrieve and move to the staging area to await an available MV-22. By defining the forklifts as resources, the entities representing the individual commodity pallets or bladders seize a forklift, utilize it, and then release for use by the next entity. Used in this manner, the forklifts no longer choose the commodity to move. The commodities themselves select them.

The landing spots on the Sea Base ship were modeled as resources because there is competition for their use from both the departing MV-22s and the returning MV-22s that require refueling. Additionally, modeling these assets as a resource simplified changing their quantity within the model for sensitivity analysis purposes. The default initial value for the number of landing spots on the Sea Base is two for all scenarios.

7. Statistics

As was mentioned at the beginning of this chapter, the number significant to this analysis is the percentage of daily sustainment requirements delivered each day. In order to capture this data, a short logic chain was added to the model. While this chain is part of the simulation model, its presence in no way affects the function of the OMFTS system being simulated.

What the logic chain does do is read the number of pallets or bladders left on the Sea Base, at the point on the Flight Deck where the commodity batches are matched with MV-22s, at 0000 hours of each day of the simulation. It also reads, also at 0000 hours, the number of pallets and bladders that arrived at the shore each day. This data is written to a worksheet file. Once the data has been captured in the worksheet file, the data will then be used to determine the daily delivery percentage. It will also be used to develop an average daily delivery percentage and standard deviation across a number of replications of the same simulation.

This logic chain also reads the time at which the last of each of the four pallet types are delivered each day. This was done to determine the utilization of the aircraft during the various days of each simulation. By knowing the time the delivery of all sustainment requirements is completed, on average, is very useful information for the operational commander who has many conflicting uses, missions and opportunities for the aviation and sea assets of his command to juggle.

Another statistical issue with this simulation is how to treat variability. Variability is introduced into the simulation in the movement times of elevators, aircraft, and forklifts as well as the refueling and maintenance times for the MV-22s. Different probability distributions, depending on the data available and the process involving the movements, govern these movement times and were discussed as they were encountered in the logic of the simulation model.

The variance of the simulation output is reduced in the simulation model by two methods. In the first instance, Arena software makes use of a random number generator that can be controlled by use of the SEEDS module. By using the SEEDS module, the starting point on the random number generator is dictated to the model. Therefore, as each replication is run, variance from any source other than the various probability distributions throughout the model is minimized, increasing the validity of the results. This is referred to as Common Random Number Variance Reduction Technique. Using the same starting point on the random number generator also allows for more valid results during sensitivity analysis by ensuring that any differences in the results are actually a result of the changes to the model inputs rather than the starting position on the generator.

In order to obtain these benefits, the SEEDS module was used in the simulation model to dictate the starting point on the random number generator for each instance where a process was governed by a distribution. This includes the various elevator and forklift movement times, refueling and maintenance processes, and the flight time between the Sea Base and the shore.

Secondly, each combination of the simulation (three force packages each at three distances) is replicated 30 times. This will produce an array of results whose distribution will approximate a normal distribution in accordance with the Central Limit Theorem. This normal distribution can then be used to make inferences about the simulation results.

V. SIMULATION RESULTS AND ANALYSIS

A. EXPERIMENT

The purpose of the experiment was to test the parameters that critically impact the ability of a LHD-class ship to provide basic sustainment requirements (food, water, fuel, ammunition) to a typical MEU(SOC) under the OMFTS concept. The critical parameters for this experiment were the size of the force deployed, which affected the quantity of sustainment requirements that were to be delivered, the initial number of aircraft assigned to the Sea Base, and the distance between the deployed forces and the Sea Base.

Recall Table 4 from Chapter III. It showed the sustainment requirements for the three different types of missions. The missions were Humanitarian Assistance/ Disaster Relief (HA/DR), Non-combatant Evacuation Operation (Non-Permissive) (NEO(N-P)), and Enabling Force. Additionally, there were two different ammunition requirements depending on whether the Marines were assaulting an objective or sustaining their position: an assault rate and a sustainment rate of ammunition consumption. Combining these two results in five different scenarios: HA/DR, NEO(N-P)(Sustain Rate), NEO(N-P)(Assault Rate), Enabling Force(Sustain Rate), and Enabling Force(Assault Rate). Because there was no ammunition expenditure for the HA/DR mission, there was no need to break out that mission according to ammunition consumption.

These five scenarios were then each tested over the three different distances between the deployed forces and the Sea Base: 50, 100, and 150 miles. This results in a total of 15 different scenarios.

Each of the 15 different scenarios was run for 30 replications in order to produce a sufficient sample size for meaningful statistical analysis. The system and statistics were set to initialize at the start of each replication.

During each of the 30 replications the total number of pallets of each of the four commodities (MRE, Ammo, Fuel, Water) was recorded on a daily basis. This was then compared to the sustainment requirement (total number of pallets of all commodities) from Table 4 to determine the daily delivery percentage. 100 percent delivery each day is, of course, the target figure. Also recorded was the time that the last pallet of each of the four commodities was delivered each day. This was done so that on the days when 100 percent delivery was achieved, a measure of aircraft utilization for that day could be extracted from the model.

There were three other measures recorded for each of the 30 replications as well. They were the number of MV-2 sorties, the number of aircraft requiring AIMD maintenance and the number of aircraft requiring minor maintenance. These measures were taken for the entire 15 days of the replication rather than on a daily basis.

B. RESULTS

Upon completion of the various scenario runs, the output data files were manipulated to calculate an average daily delivery percentage for each of the 15 days for each of the 15 different scenarios. The standard deviation was also calculated. If any day of the individual scenarios did not achieve 100 percent delivery, it was considered a failure. Table 5 summarizes the success rate of each of the 15 scenarios. Missions executed successfully are noted with a "Y", unsuccessful mission with a "N".

	Distance (miles)			
Mission	**50**	**100**	**150**	**Ammunition Rate**
HA/DR	Y	Y	Y	**N/A**
NEO(N-P)	Y	Y	Y	**Sustain**
	Y	Y	N	**Assault**
Enabling Force	N	N	N	**Sustain**
	N	N	N	**Assault**

Table 5. Mission Success Summary

These results indicate that the size of the force, which determines the quantity of sustainment requirements, and the distance between the deployed forces and the Sea Base were the key determinants that determined whether or not success was achieved for the missions.

The largest mission force package, comprised of 1500 Marines, was the Enabling Force. This results in these missions having the greatest sustainment requirements to be delivered. Additionally, missions with an assault rate of ammunition consumption added an additional 22 pallets of ammunition, 29 total pallets versus 7 total pallets for the sustainment rate, to the sustainment requirements.

Distance between the Sea Base and the forces ashore affects the outcome of the simulation in two ways. First, the larger the separation distance, the less a single MV-22 can transport in a single sortie. Table 3 in Chapter III summarized the decrease in payload that comes with increased transport distances. Second, longer flight times mean there are relatively fewer MV-22s available on the Sea Base waiting for a batch of commodities to transport ashore. Simply put, longer distances means there are more aircraft in the air at any given time compared to shorter distances.

The longer flight times and lesser payload capabilities make the availability of the aviation assets more important. Removal of a single aircraft has a greater impact on the missions with longer distances and greater delivery requirements. Removal from the mission because of maintenance requirements takes on greater importance in determining the success of the mission. For these reasons, the number of available aircraft also becomes a key determinant of the success or failure of the various missions.

Inspection of the average daily delivery percentage for each of the scenarios backs up these insights. Table 6

summarizes the daily delivery percentage results from the simulation.

			Day														
Mission	**Ammo Rate**	**Dist. To Forces**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
HA/DR	N/A	50	0	100	100	100	100	100	100	100	100	100	100	100	100	100	100
		100	0	100	100	100	100	100	100	100	100	100	100	100	100	100	100
		150	0	100	100	100	100	100	100	100	100	100	100	100	100	100	100
NEO(N-P)	S	50	0	100	100	100	100	100	100	100	100	100	100	100	100	100	100
		100	0	100	100	100	100	100	100	100	100	100	100	100	100	100	100
		150	0	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	A	50	0	100	100	100	100	100	100	100	100	100	100	100	100	100	100
		100	0	100	100	100	100	100	100	100	100	100	100	100	100	100	100
		150	0	100	100	100	100	100	100	100	100	**98**	100	**98**	**96**	**93**	**93**
Enabling Force	S	50	0	100	100	100	100	100	100	100	100	100	100	100	100	**99**	**90**
		100	0	100	100	100	100	100	100	100	**97**	**95**	**96**	**91**	**92**	**93**	**87**
		150	0	100	100	100	100	**97**	**96**	**89**	**76**	**71**	**61**	**58**	**48**	**44**	**47**
	A	50	0	100	100	100	100	100	100	100	100	**97**	**97**	**99**	**95**	**98**	**100**
		100	0	100	100	100	100	100	100	**98**	**95**	**95**	**93**	**91**	**88**	**81**	**91**
		150	0	100	100	100	**99**	**96**	**92**	**85**	**80**	**64**	**51**	**40**	**33**	**33**	**29**
S = Sustain A = Assault																	

Table 6. Daily Delivery Percentage Summary

The pattern of failure begins with the NEO(N-P) mission (assault rate) at the greatest distance, 150 miles. Failure of this mission indicates that it is the distance and the resulting increase in importance of the aircraft availability that results in mission failure. Clearly the quantity of the sustainment requirements did not exceed the capacity of the Sea Base to deliver them. Only the increase in distance from 100 to 150 miles resulted in mission failure.

Failure of each of the Enabling Force missions at all distances indicates that the quantity of sustainment requirements that must be delivered exceeds the Sea Base's ability to deliver them. Additionally, the incidence of failure occurs earlier as the distance between the forces and the Sea Base is increased. This indicates that distance continues to play a role in determining mission success or failure based on the range versus payload argument and the increased importance on the availability of a single aircraft argument.

C. SENSITIVITY ANALYSIS

The next step in the study was to conduct sensitivity analysis on the simulation parameters. Recall from the previous section that the size of the force deployed ashore, the distance between the deployed Marines and the Sea Base and the availability of the aviation assets were the most important factors that determined mission success or failure.

The size of the deployed force and the resulting sustainment requirement quantities is fixed based on the mission to be accomplished. The operational commander wouldn't send a force package suitable to accomplish a HA/DR mission to accomplish an Enabling Force mission such as assaulting an airfield or fortified position. The reverse is also true. Also, the distance that lies between the Marines ashore and the Sea Base for each scenario also remains fixed once the distance for the mission has been chosen. Additionally, the effects of increasing the distance was seen in the base experiment because each

mission was simulated at three different distances. For these reasons, sensitivity analysis focused on the availability of aircraft for the various missions.

The availability of the aircraft in the simulation model can be affected several ways. It can be directly affected by simply increasing or decreasing the number of aircraft assigned to the Sea Base at the beginning of the simulation. The availability of aircraft can also be affected by manipulating the operational availability input parameter of the simulation, the percentage of aircraft that require AIMD-level maintenance vice organizational-level maintenance, and the distribution that defines the amount of time an aircraft is delayed for AIMD-level maintenance.

Sensitivity analysis was applied to the number of aircraft input to the simulation, the operational availability of the aircraft, the number of aircraft referred for maintenance that go to AIMD-level maintenance (maintenance requirement) and the delay time associated with AIMD-level maintenance to try to gather additional useful information from this study. Additionally, the number of landing spots available on the Sea Base was also varied to see if this limited not the aircraft availability, but the aircraft’s ability to be available.

1. Landing Spots

Recall from the discussion of Landing Spots in the General Resources section of Chapter IV. In the initial simulations the landing spots on the Sea Base ship were modeled as resources because there is competition for their

use from both the departing MV-22s and the returning MV-22s that require refueling. The default initial value for the number of landing spots on the Sea Base was two for all scenarios.

Sensitivity analysis was applied to this resource to determine if the competition between MV-22s for their use affected the aircraft availability and, in turn the success or failure of the missions. The analysis used the most difficult mission to accomplish, the Enabling Force (assault rate) with a 150-mile separation distance. The number of available landing spots was increased from the value during the initial simulation (two) up to the maximum number of landing spots of a LHD-class ship (six).

Increasing the number of landing spots on the Sea Base to six had no affect on the success or failure of the mission. The results obtained for the mission simulated were exactly the same as when there were only two landing spots available.

2. Number of Aircraft

The next determinant important to the success or failure of the mission is the number of aircraft available at the beginning of the simulation. In the initial simulations there were 12 MV-22s at the beginning of each of the simulations.

The number of aircraft available at the beginning of the mission is important because of the effects of the maintenance delays. The AIMD-level maintenance delay effectively removes the affected aircraft from the rest of the simulation because of the average length of the delay.

By increasing the number of initial aircraft, the affects of this delay should be lessened because more aircraft will still be in an operational status.

To test the sensitivity of this input, the Enabling Force (assault rate) mission at 150 miles was again used as the test scenario. While there is value if any of the other missions that failed in the initial simulations can be completed with the addition of aircraft, the number of aircraft required to be able to accomplish all of the missions successfully provides the most value. As a result, using this mission, the number of aircraft was increased incrementally until the Enabling Force (assault rate) mission at 150 miles was successfully completed. The operational availability value (.85) and the percentage of aircraft requiring AIMD-level maintenance (.2) were held constant.

The minimum number of MV-22s required to successfully complete this mission was 27. This is an increase of 125 percent over the envisioned complement of MV-22s for a LHD-class ship. There was an average of 22 aircraft requiring AIMD-level maintenance across the 30 replications of the simulation.

This is a reasonable figure based on the .85 operational availability and the .2 requiring AIMD-level maintenance. In the simulation model 15 percent of aircraft returning to the Sea Base after delivery are sent for maintenance. Of this percentage 20 percent are sent to AIMD-level maintenance. This results in the diversion of three percent of all returning aircraft for AIMD-level maintenance. The number of MV-22 sorties required to

complete the mission was 714. Three percent of this number is 21.42. So the average number requiring AIMD-level maintenance of 22 is right in line with these projections. The accuracy of this measure then lends credence to the accuracy of the required increase in MV-22s of 15 to a total of 27 MV-22s required to successfully complete the most rigorous mission.

3. Operational Availability and Maintenance Requirement

Another way to increase the number of aircraft available to execute the given mission is to increase the operational availability of the embarked aircraft. This is a difficult task best addressed during the acquisition cycle. However, there are short-term solutions that can increase the operational availability of a limited number of aircraft. For instance, additional repairables can be added to the inventory of the units maintaining the aircraft to reduce the turnaround time for the AIMD-level maintenance. Or the capability of the AIMD can be increased or expanded to improve the AIMD’s ability to quickly return aircraft to service.

These examples of short-term solutions reveal the inter-connectedness of the AIMD capability and the operational availability measure. As applied to the simulation model used in this study this encompasses the .85 operational availability parameter as well as the requirement that 20 percent of aircraft requiring maintenance require AIMD-level maintenance. To explore this relationship further in terms of mission

accomplishment in the simulation model two sensitivity tests were conducted.

First, the maintenance requirement was held constant and the operational availability input was steadily increased until the most rigorous mission (Enabling Force/assault rate/150 miles) was successfully completed. Second, the operational availability parameter was held constant and the maintenance requirement was reduced until the same mission was completed successfully. In both cases the distribution governing the delay time associated with AIMD-level maintenance (exponential distribution with a mean of 25 days) was held constant at the values used in the initial simulations. Also, in both cases the expected complement of 12 MV-22s was used for the initial number of aircraft.

The results of the first test of operational availability show that an operational availability of 96 percent is required to accomplish the Enabling Force (assault rate) mission at 150 miles given the 20 percent AIMD-level maintenance requirement and the delay time distribution (EXPO(25 days)). This means that only four percent of returning aircraft can be sent for maintenance. Of these, 20 percent are then sent on to AIMD-level maintenance. In effect, in order for the mission to be successfully completed, slightly less than one percent (.008) of all returning aircraft can be sent to AIMD-level maintenance.

The results of the second test show that only when the percentage of aircraft sent on to AIMD-level maintenance is four percent or less can the mission be successfully

completed. With the operational availability constant at .85 for this sensitivity test, 15 percent of returning aircraft are sent for some type of maintenance. Of these, only four percent can be sent for AIMD-level maintenance, and the mission still be successfully completed. The percentage aircraft actually going to AIMD-level maintenance in this case is very near the one percent arrived at in the previous sensitivity test. It is .006.

These sensitivity tests show that whether the operational availability or the maintenance requirement inputs are adjusted, the results are very similar. One percent or less of all MV-22 sorties can result in AIMD-level maintenance and still provide the ability to accomplish the most rigorous mission simulated for this study. This indicates the real culprit for the mission failure is the delay time associated with AIMD-level maintenance.

Sensitivity analysis was also applied to the delay time for AIMD-level maintenance. The mean of the standard distribution defining this delay was decreased incrementally until the Enabling Force (assault rate) mission at 150 miles was successfully accomplished. Both the operational availability of .85 and the AIMD-level maintenance requirement of .2 of the base simulations were used. The results of this test showed that a 92 percent reduction of the exponential mean time for AIMD-level maintenance must be achieved in order for this mission to be successfully accomplished under the given parameters. This equates to a maximum exponential distribution mean delay time of 2,880 minutes (48 hours).

The results of this test, however, must be taken with grain of salt. Recall that the base data used in the simulations was based on NALDA database reports for Repairable Item Turn-Around Times for aviation capable amphibious ships for the period July 2000 and July 2001. The NALDA database does not break out the reporting ships data according to whether or not they were on deployment. This is significant because deployed ships experience a greater Repairable Item Turn-Around Time because of their increasing distance from reliable, shore-based supply channels. The value of the turn-around time is also greater for deployed ships because these ships have aircraft embarked onboard and are performing AIMD-level maintenance while ships in their homeport do not. Because the average turn-around time was derived from both deployed ships and ships in their homeport, the variance in the data is greatly increased resulting in greater possible delay times in the simulation model. On the other hand, if the data used to calculate the exponential mean could be isolated to only deployed ships the mean turn-around time would increase while the variance in the data would decrease. This combination of changes makes it difficult to assess the impact this would have on the overall delay time experienced in the simulation runs.

4. Operational Availability, Part II

A final sensitivity test was performed with the operational availability parameter. In the real world operation of any complex system there is quite often a disparity in the stated operational availability and the

achieved operational availability. In the case of United States Navy and Marine Corps aircraft, the achieved operational availability usually lies in the vicinity of 65 to 70 percent. This is true for both rotary and fixed-wing aircraft.

Based on an estimate of achieved operational availability of .7, sensitivity tests were conducted to determine which of the 15 original missions could be successfully accomplished and also to determine the initial number of aircraft that would be required to accomplish all 15 missions. In both cases the AIMD-level maintenance requirement of 20 percent and the original AIMD-level delay time (EXPO(36000)) were employed.

In the case of determining the total number of initial aircraft required to accomplish all missions, the result was a requirement of 53 aircraft available at the beginning of the Enabling Force (assault rate) mission with a separation distance of 150 miles.

This is a 342 percent increase over the envisioned complement of 12 MV-22s for a LHD-class ship. There was an average of 45 aircraft requiring AIMD-level maintenance across the 30 replications of this simulation. This equates to six percent of all aircraft returning from delivery sorties. And this increase is a 105 percent increase from the average number of aircraft requiring AIMD-level maintenance under the .85 operational availability sensitivity test.

The final sensitivity test was to determine which of the 15 missions could be successfully accomplished given a

.7 achieved operational availability value. Table 7 summarizes the results of this test.

	Distance (miles)			
Mission	**50**	**100**	**150**	**Ammunition Rate**
HA/DR	Y	Y	N	**N/A**
NEO(N-P)	N	N	N	**Sustain**
	N	N	N	**Assault**
Enabling Force	N	N	N	**Sustain**
	N	N	N	**Assault**

Table 7. Mission Success Summary
.70 Achieved Operational Availability

As can be seen from this table, the capability of the Sea Base to provide the required sustainment requirements is drastically reduced when the achieved operational availability is only .70.

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VI. CONCLUSIONS AND RECOMMENDATIONS

The objective of this study was to analyze the capability of a current LHD-class ship to provide sustained logistic support to Marine units deployed ashore under the OMFTS concept.

A. CONCLUSIONS

1. The current LHD-class ship is capable of sustaining forces deployed ashore only under OMFTS concepts for a limited time.

The LHD is capable of successfully sustaining the Humanitarian (HA/DR) missions at any separation distance and all of the Evacuation (NEO(N-P)) missions except at the assault rate of ammunition expenditure and a separation of 150 miles.

However, it is only capable of sustaining the Enabling Force missions for short periods of time. If this force uses a sustaining rate of ammunition expenditure, the force can be successfully, 100 percent sustained for 13, eight, and five days at 50, 100, and 150 miles respectively. Under the assault rate of ammunition expenditure, the force can be sustained for nine, seven, and four days at 50, 100, and 150 miles respectively.

OMFTS, however, is about projecting United States military power ashore. And sustaining that projected power until national objectives are met. It is this with which

the Enabling Force missions were primarily concerned. While it is useful to be able to successfully execute humanitarian and evacuation missions, this does not achieve national objectives or interests. Projecting power ashore does. So, placing time limits on the Enabling Force to accomplish its missions must be considered a failure to achieve the objectives of OMFTS at the present time.

Several more conclusions can be drawn from the results of this study. These conclusions concern the number of transport aircraft needed to successfully complete the required missions, the operational availability of the transport aircraft, and the AIMD-level maintenance turn-around time. Keep in mind too, that each of these three topics are intertwined and cannot be completely separated as each is dependant on the others for its value.

2. The proposed complement of 12 MV-22 aircraft for a LHD-class ship is insufficient to accomplish all required sustainment missions with the given sustainment requirements and maintenance factors.

The number of MV-22s used in the initial simulations was 12, the intended complement for a LHD-class ship. However, with an operational availability of .85, a minimum of 27 MV-22s is needed to accomplish all the Enabling Force missions. With an achieved operational availability of .70, a total of 53 MV-22s is required to accomplish all of the sustainment missions.

Even if the MV-22 achieves its intended operational availability of .85, there are no where near enough of

these aircraft embarked on the LHD to achieve the Enabling Force missions. And, there is not enough space onboard a LHD to increase the MV-22 complement to the required number of 27, let alone 53. So the question becomes, where will the additional transport capability come from?

The simulations run for this study included only a single ship Sea Base, the LHD, because this is the ship around which current ARGs are most often built. OMFTS, however, envisions more than one air capable ship making up the Sea Base. Could sufficient MV-22s be embarked on all ships of the Sea Base to meet the mission needs? That will depend on the number and type of ships that constitute the Sea Base. Additionally, OMFTS also envisioned a CVBG being located near the Sea Base to provide protection and support for both the Sea Base and the deployed forces. Not only is this a resource to embark additional MV-22s, but at the least the aircraft carrier at the center of the battlegroup contains AIMD-level maintenance capabilities. This, of course, would help to return the MV-22 to mission capable status more quickly. Of course, the carrier AIMD is most concerned with its own complement of aircraft, but any slack time could be devoted to MV-22 maintenance. What the value of that would be is indeterminate at this time, however.

3. The current average AIMD-level maintenance delay of 25 days for aircraft must be brought down significantly in the case of the MV-22 in order to successfully accomplish the required sustainment missions.

As mentioned in the previous section, there are two different operational availability figures to consider for the MV-22 and accomplishment of the missions of this study. These are the planned operational availability of .85 and the achieved operational availability that was estimated at .70 based on experience with other Naval aircraft. With the given AIMD-level maintenance delay time, neither figure for operational availability was capable of providing sufficient aircraft to accomplish all of the assigned missions.

Sensitivity analysis showed that, in fact, an operational availability of .96 was required to accomplish the missions with the heaviest sustainment requirement load. It is practically impossible to achieve a system operational availability this high. The developmental, provisioning, life-cycle and other acquisition costs preclude achievement of a figure this high.

On the other hand, with a .85 operational availability, only 27 MV-22s are needed vice 53 at the .70 operational availability figure. Certainly, it is much easier to find room on the various Sea Base ships for an additional 15 MV-22s rather than an additional 41.

There is difficulty, however, in achieving even the .85 operational availability figure as evidenced by the achieved operational availability figure for most Navy airframes of .70. Operational availability is a function

of both the Mean Time Between Maintenance (MTBM) and the Maintenance Down Time (MDT) for the aircraft. A poor achieved operational availability points to insufficient MTBM and an excessive MDT.

While actual MTBM and MDT figures from fleet operations are currently unknown for the MV-22, the NALDA database that was used to derive the AIMD-level maintenance delay time provide insight into the MTBMs and MDTs the acquisition system has been able to provide the Navy's current inventory of rotary and fixed-wing aircraft. If the MV-22 follows form it will experience a similar lengthy average delay time and the resulting low operational availability. And that points the finger for the failure to achieve the missions of this study at the excessive AIMD-level maintenance delay time. The MTBM must be of sufficient length and the MDT of sufficient brevity to achieve the .85 target. The average delay of 25 days experienced currently must be brought down significantly.

4. The sustainment requirements for forces deployed ashore need to be reduced. Fuel and water requirements are the most difficult requirements to transport, but also provide the most promise for realizing reductions.

While the level of sustainment requirements was fixed according to the number and type of forces and equipments deployed, their volume was a significant factor in the success or failure of the sustainment missions. A clear pattern emerges between the missions (HA/DR and NEO) requiring lesser sustainment requirements and the Enabling Force missions. The HA/DR and NEO missions either never

failed or failed only at the greatest distance when the maintenance delay time exerted influence over the success or failure of the mission. However, all of the Enabling Force missions failed at some point in time short of the 15-day sustainment target as a result of the increased requirement for sustainment.

The difference makers, as it were, were the water and fuel bladders. The Enabling Force missions required significant increases in these two commodities over the NEO(N-P) and HA/DR missions. Water requirements increased almost 300 percent and fuel requirements increased 100 percent.

Because of the weight of these containers, this increase in requirements significantly increased the number of sorties required to transport these commodities ashore. At the shortest distances, water bladders can only be transported two at a time and fuel bladders three at a time. At the longest distances both can only be transported a single bladder at a time. This requires a minimum number of 39 daily sorties just for the fuel and water requirements at the longest distance and a minimum of 17 daily sorties at the shortest distance.

As has been demonstrated, the more sorties that are required the better the chance that the extended maintenance delay times will affect the outcome of the mission. Therefore, the increase in requirements for the Enabling Force provided a significant impact on the ability of the Sea Base to accomplish these sustainment missions.

B. RECOMMENDATIONS

The sustainment missions of this study that failed failed because there were insufficient aircraft, excessive AIMD-level maintenance delay times, and excessive sustainment requirements to be delivered. These three situations need to be addressed in order to ensure a LHD-class ship or any future ship designed to accomplish operational missions with OMFTS concepts to ensure the forces deployed ashore can be properly sustained.

1. Ensure there is adequate embarkation space on the ships of the Sea Base to accommodate sufficient numbers of MV-22s to accomplish the sustainment mission.

The lower the achieved operational availability, the more space that will be required. Sufficiently low operational availability will force decisions on the force commander they do not want to make. More MV-22s or the regular complement of AV-8s, CH-53s, or other airframe types? The space and maintenance requirements of the true required number, not the number based on contractor operational availability claims, of MV-22s to accomplish the mission must be taken into account when the ship types are chosen or developed as part of the OMFTS Sea Base.

2. Reduce the AIMD-level maintenance turn-around time (MDT) for the MV-22 through improved repairable item turn-around time and decreased procurement lead times and transportation times.

Excessive delays on non-mission capable aircraft, whether waiting for maintenance or repairables, drive down operational availability and drive up the number of required aircraft to successfully accomplish the sustainment mission.

While it may be too late to affect the MTBM of the MV-22 at this point in its acquisition cycle, the MTBM should still be studied to determine the true operational MTBM as well as ways to improve this measure in the future.

The MDT, on the other hand, is ripe for improvement. MDT is made up of not only actual maintenance time, but also logistics delay time (LDT) and administrative delay time (ADT). Logistics delay time is probably the most important driver of high MDTs. Naval activities are consistently faced with declining budgets to purchase spares that increase in cost each year as well as lengthy procurement delay times when no spares are available in the supply system. Additionally, transportation times to deployed ships adds significant amounts of time to the MDT.

3. Reduce the quantity of sustainment requirements to be delivered ashore via MV-22.

This can be accomplished in several ways. First, more fuel-efficient vehicles should be developed in order to reduce the fuel burden. Second, find ways to reduce the

quantity of water used by the forces ashore. There are minimum required quantities based on sanitation, maintenance, and food preparation to any reduction in water usage, but methods of recycling some water that can reduce the overall gallon per man requirement should be engineered. Third, while not considered in this study, unmanned aerial vehicles could be developed to deliver some sustainment loads. Certainly, if they can deliver Hellfire missiles into the mouth of a cave in Afghanistan, they can be adapted to deliver sustainment requirements. Development of vehicles such as this would reduce the burden on the MV-22 at a price far less than the MV-22.

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